9. Total target strength measurements of Antarctic zooplankton and nekton; submitted by Stephane Conti (Leg II) and David A. Demer (Leg II).

9.1 Objectives: Measure total target strength (*TTS*) over a wide acoustical bandwidth for multiple species of Antarctic zooplankton and nekton. These experiments are preliminary to the development of an improved classification method for the three-frequency echo sounder data.

9.2 Methods and Accomplishments: *TTS* was measured for multiple species using a new technique first described by De Rosny and Roux (2001). In this application, 200 sound pulses at each frequency (36-202kHz) were sequentially transmitted into a highly echoic tank containing swimming animals of a single species. For each pulse, the animals took different positions within the fixed-boundaried-tank and the modulated reverberation was recorded. The coherent energy in 200-pulse ensembles identified sound scattered from the echoic tank. Because the positions of the animals were uncorrelated from ping-to-ping, the incoherent energy described sound scattering from the animals. Thus, the *TTS* at each frequency was extracted from an analysis of the coherent and incoherent energy reverberated in the tank. Previously, Demer and Conti *et al.* (submitted) used precision metal spheres to demonstrate that the method has potential for remarkable accuracy (0.4dB) and precision (±0.7dB).

The experimental apparatus included: a computer, arbitrary waveform generator, power amplifier, wide-bandwidth transducer used as an emitter, three omnidirectional hydrophones, an analog-to-digital converter, a digital thermometer, and three glass carbuoys (volumes = 9.3, 19.3, and 45.9 liters), as shown on Figure 9.1. Carbuoys were used for echoic tanks so as to maintain fixed boundaries while operating on a moving ship. The choice of cavity volume depended on the numbers and sizes of animals available from the Isaacs-Kidd Midwater Trawl (IKMT) catches.

To make *TTS* measurements, a carbuoy was filled with seawater, then the live animals, and closed with a rubber stopper holding the transducer, three hydrophones, and a thermocouple (Figures 9.2A & C). For each frequency from 36 to 202kHz, the computer generated a chirp signal with 0.5ms duration. The signals were sequentially transferred to the arbitrary waveform generator that repeated each 2kHz-bandwidth chirp 200 times at a 0.5-Hz repetition rate. The amplified signals were transmitted into the carbuoy; reverberation time-series were simultaneously received by each of three hydrophones, digitized at 410kHz, and stored on hard disk. All of the experimental data were saved on hard disk for analyses and then compressed and stored on compact disk for archive.

As these were the first *TTS* measurements to be made in the field, the measurements were baselined without the motion and noise of the ship. From 18 to 22 February, the first ever *TTS* measurements of krill were thus made at the Cape Shirreff field station. Each morning, krill captured with the IKMT were transferred ashore via zodiac in 20-l buckets of seawater and other assorted containers. Depending upon the supply, groups of 57 to 1,169 krill were then moved into 9.3, 19.3 or 45.9-l glass carbuoys for the *TTS* measurements. Following the acoustical measurements, animal lengths were measured to the nearest millimeter before preserving them in sample jars with ethanol. At the conclusion of the near-shore survey operation, *TTS* measurements continued aboard R/V *Yuzhmorgeologiya* throughout the remainder of Leg II. More krill data were acquired, as well as data from myctophids, a squid, and *Cyllopus* spp.

9.3 Results and Tentative Conclusions: The measurements were focused on Antarctic krill (*Euphausia superba*, Figure 9.2B), with some *TTS* measurements made of myctophids (*Electrona antarctica*, Figure 9.3; *Gymnoscopelus braueri*, Figure 9.4; *and Gymnoscopelus nicholsi*) and *Cyllopus* spp. and a squid (Figure 9.5). The mean *TTS* of *E. superba* were realized with 57 to 1,169 krill per carbuoy (Figure 9.6). The groups of krill had a variety of length-frequency distributions (Figure 9.7) having an overall average length of 31.6mm. After low-pass filtering the reverberation time-series, the *TTS* measurements of krill made shipboard were favorably compared to those made at Cape Shirreff. The *TTS* measurements of krill at frequencies below about 60kHz had an increased standard deviation (sd). Therefore, the elevated mean values at those frequencies may not be accurate. Additional analysis of the data from the 13mm diameter copper calibration sphere may help to validate those measurements.

The *TTS* and mean *TTS* of *E. antarctica* were recorded from single myctophids and groups of up to four fish (Figure 9.8). Again, some of the *TTS* measurements below about 60kHz were elevated and had large standard deviations. The mean *TTS* of a single squid was also estimated from four wide-bandwidth runs (Figure 9.9). A comparison of the mean *TTS* measurements for krill, myctophids, and squid (Figure 9.10) shows distinctly different scattering spectra for these three taxa. Although the slopes of *TTS (frequency)* are similar, the amplitudes are separated by about 5 to 20dB. This degree of separation should be sufficient to acoustically delineate the three scattering taxa.

Some of the *TTS* measurements were not accurate because the subjects were not adequately moving. The *TTS* of *Cyllopus* spp. are not reported because their scattering cross-sections were too small to be accurately measured with the method as implemented. The remaining measurements were deemed of good quality (Table 9.1), bar an increased standard deviation for some measurements below about 60kHz.

9.4 Disposition of Data: Data are available from Stephane Conti and David Demer, Advanced Survey Technologies Program, Southwest Fisheries Science Center, 8604 La Jolla Shores Drive, La Jolla, CA 92037; phone/fax: +1 (858) 546-5691/5608; Stephane.Conti@noaa.gov; David Demer, phone: +1 (858) 546-5603; David.Demer@noaa.gov.

9.5 Acknowledgements: We are especially thankful to the Captain and all crew members of R/V *Yuzhmorgeologiya*, and to all the members of the zooplankton team (Nancy Gong, Emma Bredesen, Shelly Peters, Lorena Linacre-Rojas, Mike Force, Adam Jenkins, Valerie Loeb, and Rob Rowley) for providing us with live animals from the IKMT catches. Thanks to Rennie Holt for allowing us to conduct the experiments at both Cape Shirreff field station and aboard the ship, and to Rob Rowley for designing and constructing a very useful equipment rack for transporting the electronics to and from the island. Finally, thanks to the team at Cape Shirreff (Iris Saxer, Brian Parker, Dana Scheffler, Wayne Trivelpiece, and John Lyons) for their hospitality during our stay.

9.6 References:

De Rosny, J., and Roux, P. 2001. Multiple scattering in a reflecting cavity: Application to fish counting in a tank. *Journal of the Acoustical Society of America* 109:2587-2597.

Demer, D.A., Conti, S., De Rosny, J., and Roux, P., submitted. Absolute measurements of total target strength from reverberation in a cavity. *Journal of the Acoustical Society of America.*

Table 9.1 Total target strength measurements by species, date, and carbuoy volume.

Euphausia superba

Good	Date	Loc	Vol (l)	Num	Pings	Freq (kHz)	RX(s)	# RX	Rec (ms)	fs (kHz)	W temp.
	21802	C.S.	19.3	10	200	36:2:110	ITC1042	1	32	500	
	21802	C.S.	19.3	10	200	36:2:202	ITC1042	1	32	500	2.9
	21802	C.S.	9.3	2	200	36:2:202	ITC1042	1	32	500	3.5
	21902	C.S.	9.3	26	200	36:2:202	1042&4013	2	32	500	1.6
	21902	C.S.	9.3	5	200	36:2:202	Reson 4013	3	32	410	2.7
X	22102	C.S.	9.3	302	200	36:2:202	Reson 4013	3	20	410	3.6
X	22202	C.S.	9.3	100	200	36:2:202	Reson 4013	3	20	410	1.6
	22202	C.S.	9.3	50	200	36:2:202	Reson 4013	3	20	410	2.3
	22202	C.S.	19.3	30	200	36:2:202	Reson 4013	3	30	410	3.2
X	22302	C.S.	9.3	60	200	36:2:202	Reson 4013	3	20	410	3.4
X	22402	C.S.	19.3	60	200	36:2:202	Reson 4013	3	20	410	4.0
X	22602	Yuz	49.7	1169	200	36:2:202	Reson 4013	3	32	410	3.7
X	22702	Yuz	19.3	326	200	36:2:202	Reson 4013	3	20	410	2.0
X	30802	Yuz	19.3	258	200	36:2:202	Reson 4013	3	10	410	0.6
X	30802	Yuz	9.3	152	200	36:2:202	Reson 4013	3	10	410	2.5
X	30802	Yuz	9.3	86	200	36:2:202	Reson 4013	3	10	410	3.4
X	30902	Yuz	19.3	173	200	36:2:202	Reson 4013	3	10	410	1.4
X	30902	Yuz	9.3	176	200	36:2:202	Reson 4013	3	10	410	2.3
X	30902	Yuz	19.3	117	200	36:2:202	Reson 4013	3	10	410	3.1

Electrona antarctica

Good	Date	Loc	Vol (l)	Num	Pings	Freq (kHz)	RX(s)	# RX	Rec (ms)	fs (kHz)	W temp.
	22802	Yuz	19.3	3	200	38,70,120,200	Reson 4013	3	20	410	2.4
X	22802	Yuz	19.3	4	200	36:2:202	Reson 4013	3	20	410	2.4
X	30402	Yuz	19.3	3	200	36:2:202	Reson 4013	3	20	410	2.6
	30402	Yuz	19.3	3	200	36:2:202	Reson 4013	3	20	410	2.6
X	30502	Yuz	9.3	1	200	36:2:202	Reson 4013	3	10	410	2.2
X	30602	Yuz	9.3	1	200	36:2:202	Reson 4013	3	10	410	1.1
	30702	Yuz	9.3	1	200	36:2:160	Reson 4013	3	10	410	1.0
X	30702	Yuz	9.3	1	200	36:2:202	Reson 4013	3	10	410	1.5
	30802	Yuz	9.3	1	200	36:2:156	Reson 4013	3	10	410	1.7
X	30802	Yuz	19.3	1	200	36:2:202	Reson 4013	3	10	410	2.2

Gymnoscopelus nicholsi

Good	Date	Loc	Vol (l)	Num	Pings	Freq (kHz)	RX(s)	# RX	Rec (ms)	fs (kHz)	W temp.
	30602	Yuz	19.3	2	200	36:2:184	Reson 4013	3	10	410	1.2

Gymnoscopelus braueri

Good	Date	Loc	Vol (l)	Num	Pings	Freq (kHz)	RX(s)	# RX	Rec (ms)	fs (kHz)	W temp.
	30402	Yuz	19.3	3	200	36:2:202	Reson 4013	3	20	410	2.6
	30702	Yuz	19.3	1	200	36:2:174	Reson 4013	3	10	410	1.5

13mm diameter copper sphere

Good	Date	Loc	Vol (l)	Num	Pings	Freq (kHz)	RX(s)	# RX	Rec (ms)	fs (kHz)	W temp.
X	22102	C.S.	9.3	1	200	36:2:202	Reson 4013	3	32	410	10.3
X	31202	Yuz	19.3	1	200	36:2:202	Reson 4013	3	10	410	3.5

Empty Tank

Good	Date	Loc	Vol (l)	Num	Pings	Freq (kHz)	RX(s)	# RX	Rec (ms)	fs (kHz)	W temp.
	21702	C.S.	19.3	0	100	36:2:202	ITC1042	1	32	500	
	21702	C.S.	19.3	0	100	45:20:185	ITC1042	1	32	500	
	21802	C.S.	9.3	0	100	36:2:202	1042&4013	2	32	500	
	22002	C.S.	9.3	0	100	36:2:202	Reson 4013	3	32	410	10.2
X	22102	C.S.	9.3	0	100	36:2:202	Reson 4013	3	20	410	11.0
X	30202	Yuz	19.3	0	100	36:2:202	Reson 4013	3	20	410	3.0

Squid

Good	Date	Loc	Vol (l)	Num	Pings	Freq (kHz)	RX(s)	# RX	Rec (ms)	fs (kHz)	W temp.
X	30902	Yuz	9.3	2	200	36:2:202	Reson 4013	3	10	410	3.6

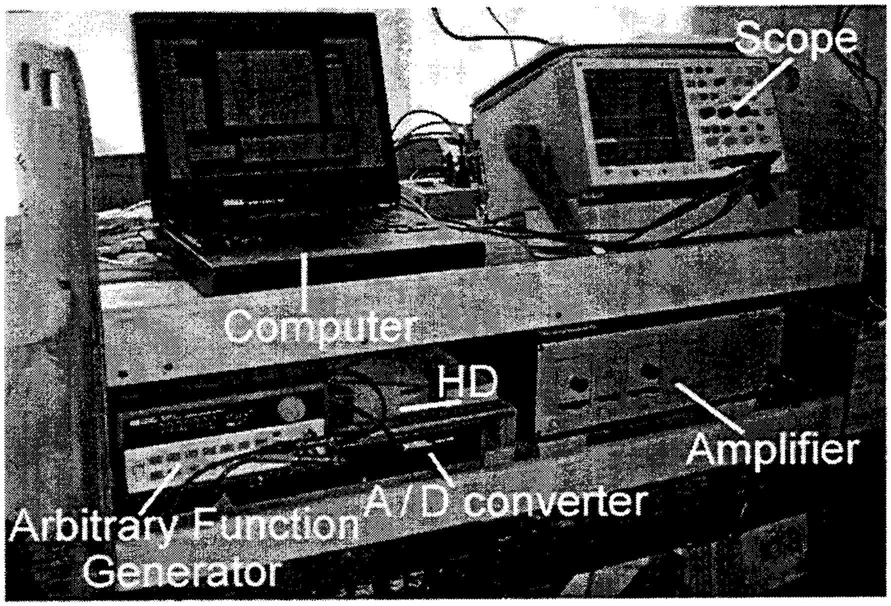

Figure 9.1. Experimental apparatus.

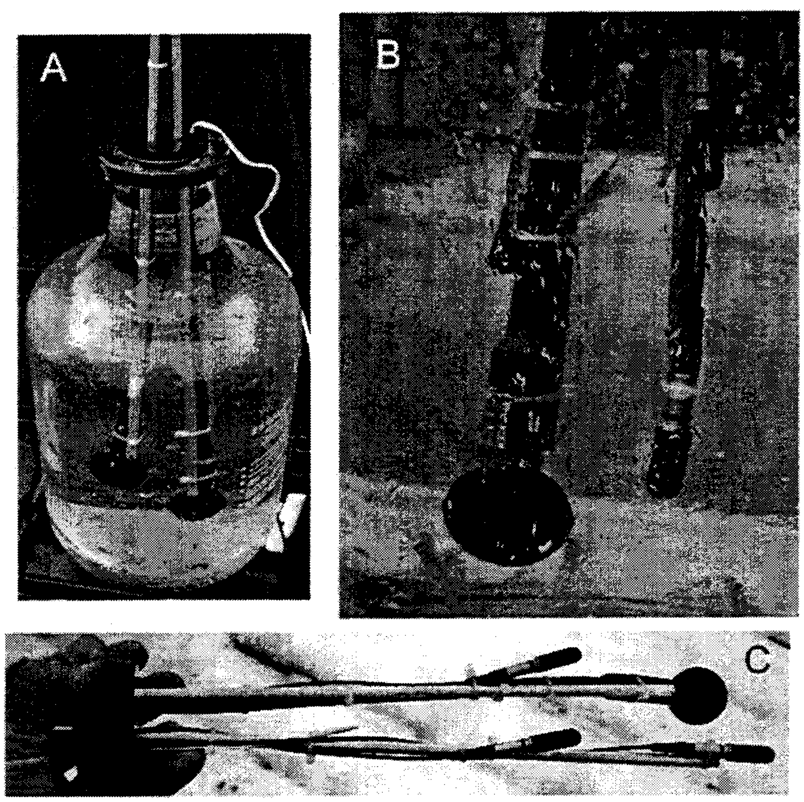

Figure 9.2. (A) 9.3-l carbuoy with transducer, hydrophone, thermocouple, and krill at Cape Shirreff field station; (B) *E. superba* in the 19.3-l carbuoy during the experiments aboard R/V *Yuzhmorgeologiya*; (C) and a rubber stopper fitted with the transducer (projector), three hydrophones, and a thermocouple.

Figure 9.3. *Electrona antarctica*

Figure 9.4. *Gymnoscopelus braueri*

Figure 9.5. The squid.

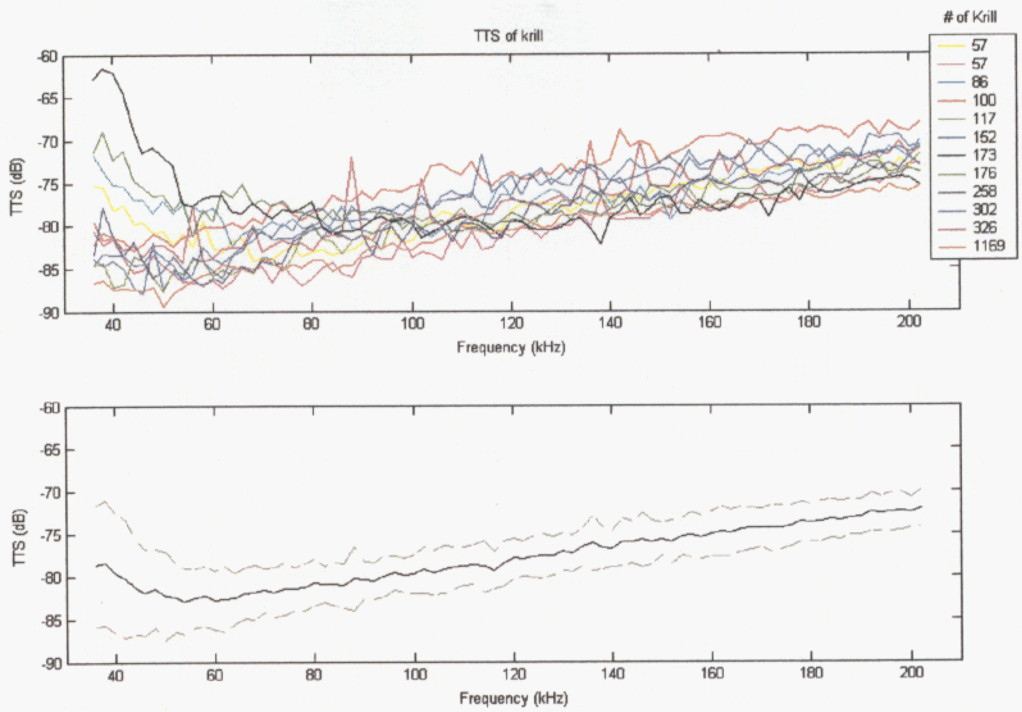

Figure 9.6. Mean *TTS* of *E. superba* measured from aggregations totaling 57 to 1,169 animals (top). The average of all runs is plotted with ±1 sd error bars (bottom).

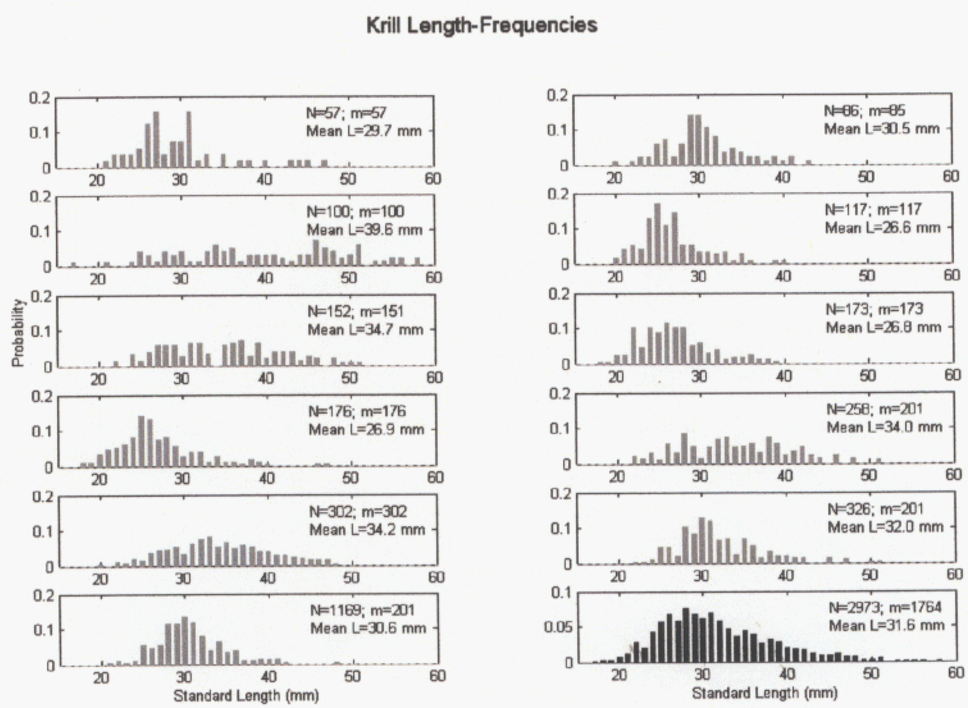

Figure 9.7. Krill length-frequencies are shown for each batch of krill measured (gray) and all of the krill combined (black).

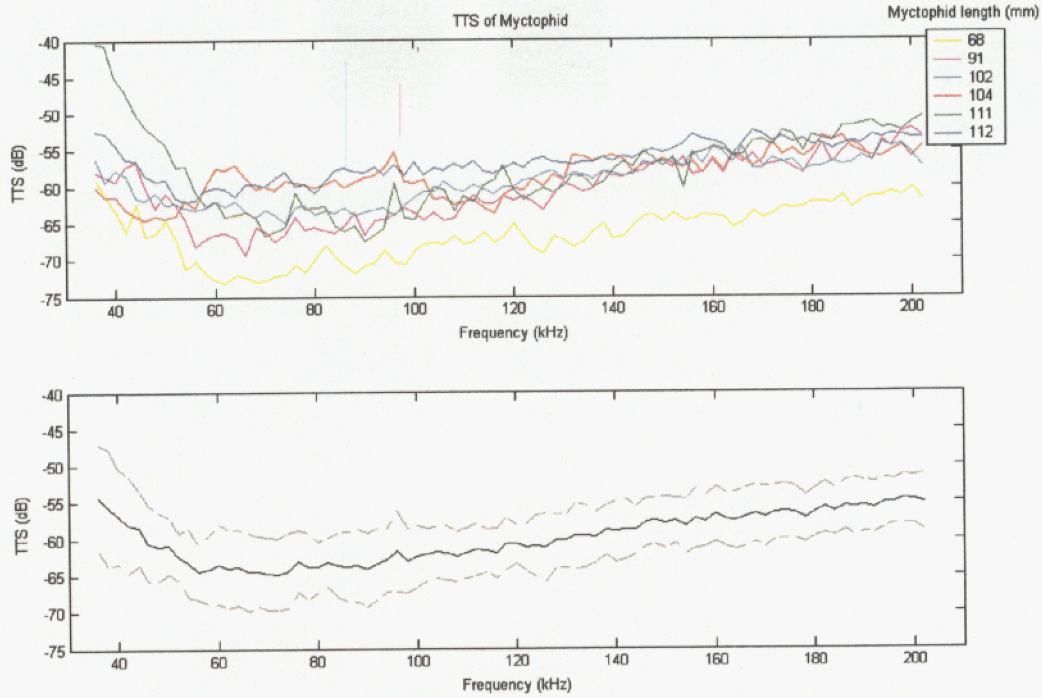

Figure 9.8. *TTS* and mean *TTS* of *E. antarctica* measured from individual fish and groups of up to 4 fish, respectively (top). The average of all measurements is plotted with ±1 sd error bars (bottom).

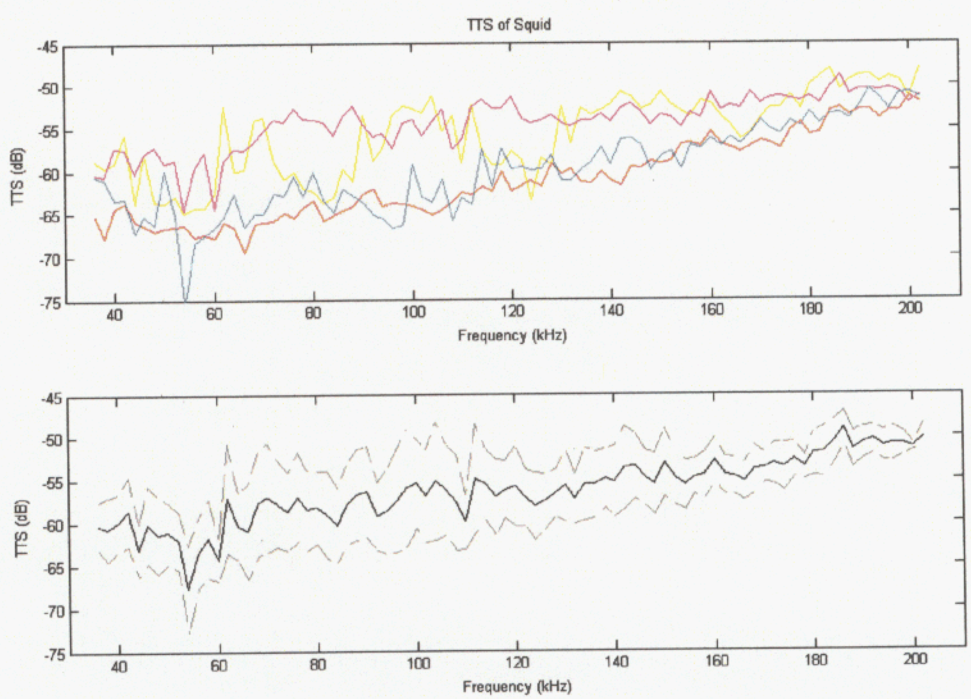

Figure 9.9. Mean *TTS* of a squid (top) estimated from the signals received at three hydrophones in each of four wide-bandwidth scans. The average of all measurements is plotted with ±1 sd error bars (bottom).

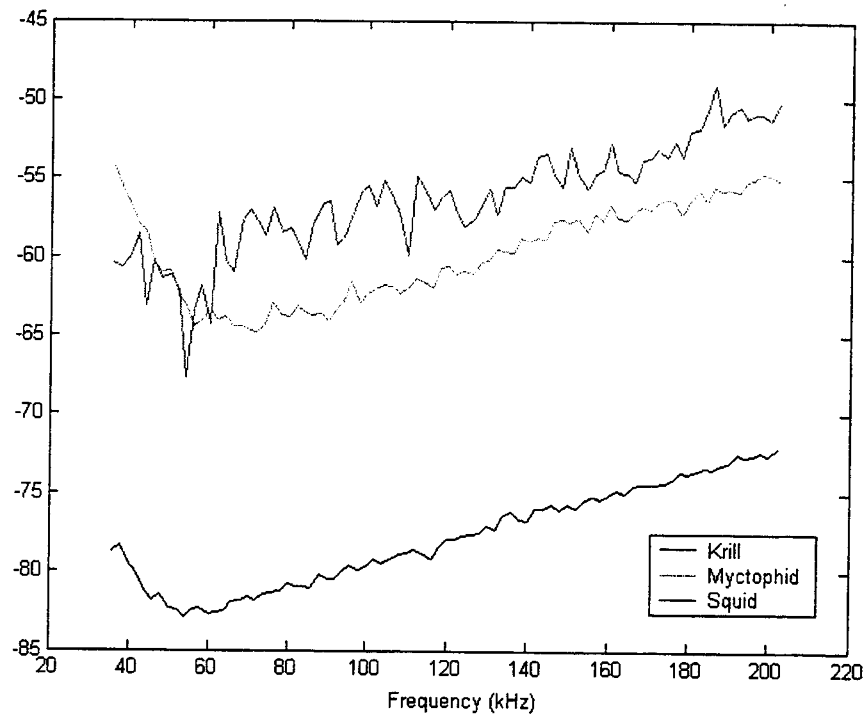

Figure 9.10. Comparison of the mean *TTS* of *E. superba, E. antarctica* and a squid.